REMARKS

Reconsideration and allowance of this application are respectfully requested in light of the above amendments and the following remarks.

Claims 1-6 and 11-16 stand rejected under 35 USC § 103(a) as being unpatentable over Davis et al. (U.S. Patent No. 6,051,849) in view of Tokunaga et al. (U.S. Patent No. 5,425,808) and Nakamura et al. (Japanese Patent No. 01-234389). The Applicant respectfully traverses this rejection.

The Office Action asserts that Davis et al. teach each of the features of the rejected claims except for "forming an amorphous film" and the particular incidence angle of the atomic beams, i.e., not more than 40 degrees with respect to the substrate surface. Accordingly, the Office Action introduces Togunaga et al. to provide a teaching of growing a GaAs film of an amorphous SiO_2 or Si_3N_4 film. In addition, Nakamura et al. is added to provide a teaching of an angle of incidence for the atomic beam.

However, the Applicant notes that Davis et al. disclose a so-called ELO technique in which a SiO_2 patterned mask is formed on a GaN underlayer, and then, a given GaN film is formed on the

GaN underlayer via the SiO_2 patterned mask (see Figs. 1-5 and columns 4 and 5). According to the ELO technique, initially, the GaN film is epitaxially grown vertically so as to embed the opening of the SiO_2 mask, and then, it is laterally grown on the SiO_2 mask. In this case, the dislocation density of the GaN film is reduced to $104/cm^2$ or below (see column 4, lines 25-27). That is, a high crystallinity GaN film is disclosed.

Tokunaga et al. disclose an ELO technique, similar to that of Davis et al., in which a given GaAs film is epitaxially grown on a GaAs substrate via an amorphous SiO2 patterned mask or a Si_3N_4 patterned mask. Moreover, Tokunaga et al. exemplify a film-forming technique such as vacuum deposition, sputtering , IVIBE or CVD.

Moreover, Nakamura et al. disclose an MBE apparatus in which a molecular beam source is disposed opposite to a substrate, and the main surface of the substrate is rotated to the molecular beam source by an angle θ .

The Office Action asserts, with reference to Davis et al. and Tokunaga et al., that it is well known to form a high crystallinity GaAs film on a film having an opening and made of, e.g., an amorphous SiO_2 by a CVD method. In addition, the Office

Action states that Tokunaga et al. disclose a MBE method and a CVD method as being equal film-forming techniques, and Nakamura et al. teach that the preferable incident angle of a molecular beam for the main surface of the substrate is within 0-90 degrees.

As mentioned above, however, Davis et al. and Tokunaga et al. disclose only an ELO technique to be used in a CVD method. Because ELO techniques require the substrate and the underlayer to be made of the same material as that of a film to be formed, the film made of the same material is formed on the substrate or the underlayer.

In contrast, the present claimed invention involves epitataxially growing a film in high crystallinity on a substrate or an underlayer even made of *any* material different from the one of the film, and need not be limited to the *same* material for the film and substrate.

New claim 17 has been added to recite that the substrate and the film are of different materials, as supported throughout the specification, in particular page 8.

The present claims recite the use of an MBE method and the incident angle of 40 degrees or below. In fact, in Example 6 of

this specification of this application, it is disclosed that the incident angles of a As_4 molecular beam and a Ga atomic bearm are set to 20 degrees and 40 degrees, respectively, to epitaxially grow a GaAs film of single crystal on a substrate made of Si single crystal different from GaAs. On the other hand, in Davis et al., for example, a GaAs single crysatalline film is formed on an underlayer made of the same GaAs as the film by a CVD method.

Applicants additionally assert that in a CVD method, raw material gases which contain constituent elements of a film to be formed are supplied onto a substrate heated. Accordingly, the raw material gases are decomposed, and the thus obtained constituent elements thermochemically react with one another to form the film desired. Therefore, the directionality of the raw material gases are not an important matter, and the sort of the material and the crystallinity of the substrate or the underlayer on which the film is formed are important matters.

In contrast, in an MBE method, the constituent elements of a film to be formed are directly supplied as a molecular beam or an atomic beam onto a substrate, and then, are reacted with one another directly without the thermal decomposition. Therefore, the directionality of the molecular beam or the atom beam is an

important matter. As a result, the principles and the mechanisms of the MBE method is quite different from those of the CVD method. Tokunaga et al. only disclose well-known film-forming methods, having different principles and mechanisms. If the CVD method were like the MBE method, the CVD method would be also similar to a sputtering method.

In the MBE apparatus disclosed in Nakamura et al., the angle θ can be varied within 0-90 degrees, but the preferable incident angle of the molecular beam is not proposed. That is, when the angle θ is varied within 0-90 degrees, the incident angle is also varied within 0-90 degrees, which corresponds to *all* ranges of incident angles. That is to say, if the molecular beam is introduced onto the substrate, it is clear that, the incident angle must be set within 0-90 degrees. If an incident angle of less than 0 degrees or more than 90 degrees is set, the molecular beam is then introduced onto the backside surface of the substrate, not the main surface. As a result, Nakamura et al. do not teach the preferable incident angle as disclosed in this application, as the disclosure of 0-90 degrees is inherent in all incident angles used in depositing a molecular beam on a substrate.

Furthermore, it is the present Applicants who have particularly selected the narrower "not more than 40 degrees" for the incident angle. As discussed throughout the present specification, the incident angle is selected to form a uniform single crystalline film, selectively and epitaxially on the exposed part of the substrate.

In view of the above, it is respectfully submitted that all objections and/or rejections are overcome and that all pending claims are directed to allowable subject matter. Thus, a Notice of Allowance is respectfully solicited.

If any issues remain which may best be resolved through a telephone communication, the Examiner is requested to telephone the undersigned at the local Washington, D.C. telephone number listed below.

Respectfully submitted,

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A Method for Forming a Single Crystalline Film

09/511,912

35 USC §103 Rejection

- Claims 1-6, 11-18, 20-23
- Tanaka, Tokunaga, Nakamura
- Claim 1 recites:
  - A method for forming a single crystalline film comprising the steps of:
    - forming an amorphous film on a single crystalline substrate,
    - forming an opening in the amorphous film and thereby exposing a part of a surface of the substrate, and
    - introducing atomic beams, molecular beams or chemical beams onto the surface of the substrate at their incident angle of not more than 40 degrees with respect to the substrate surface under a reduced atmosphere and thereby selectively and epitaxially growing a single crystalline film on the exposed surface of the substrate.

Claim 1 Rejection

- Office Action states:
  - Nakamura discloses a molecular ray method of performing epitaxy (page 4, 2nd ¶)
  - Obvious to combine Nakamura with Tanaka & Tokunaga because Nakamura discloses optimization of the angle of incidence between the substrate and the molecular ray in order to affect the product
  - The motivation for combining would be the optimal crystal formed thereby

Claim 1 Rejection, cont'd

- Applicant discloses in Figs. 1-3:
  - Molecular beam particles 6-1 and 6-3 that impinge on amorphous film 2 are entirely reflected, or nearly so, with few if any of the particles being deposited on amorphous film 2 (Fig. 1 & specification, page 3, lines 16-19)
  - Molecular beam particles 6-2 impinging on an exposed surface 1A of single crystalline substrate 1, through opening 3, are almost entirely deposited without any being reflected (specification, page 3, lines 19-21)
  - Referring now to Fig. 2, as particles 6-2 continue to be deposited in opening 3, the deposited single crystalline film 7 grows up and out of opening 3 such that its upper surface 7a is higher than the upper surface of the surrounding amorphous film 2 (specification, page 3, lines 23-25)
  - Also, side surface 7B of the deposited film 7 becomes exposed to the molecular beam.
  - With side surface 7B exposed, molecular beam particles 6-5 impinging on side surface 7B begin to deposit on single crystalline film 7 without being reflected (specification, page 3, line 27, through page 4, line 3)
  - As illustrated in Fig. 3, a lateral single crystalline film 9 grows laterally overtop of amorphous film 2 as the epitaxial growth continues on side surface 7B (specification, page 4, lines 6-8)

Claim 1 Rejection, cont'd

- Nakamura discloses in Figs. 1 & 2:
  - Epitaxial growth is optimized when a molecular beam from source 2 strikes a substrate 6 at an angle perpendicular to its surface
  - Rate of epitaxial growth decreases as the angle at which the molecular beam strikes the substrate surface decreases from 90 degrees to zero degrees

Claim 1 Rejection, cont'd

- Evaluating Nakamura in light of proposed motivation to combine teachings
  - Office Action states Nakamura discloses optimizing the angle of incidence between the substrate and the molecular beam to positively affect the product (Office Action, page 4, 3rd ¶)
  - Nakamura discloses that the product is increasingly positively affected by reducing the angle between the molecular beam and an angle perpendicular to the substrate surface (Figs. 1 & 2)
  - Additionally, Nakamura discloses that the optimal positive effect on the product is achieved by directing the molecular beam perpendicular to the substrate's surface
  - Epitaxial lateral overgrowth provided by Applicant's method of claim 1 is substantially incapable of being achieved by a molecular beam directed perpendicularly to the substrate surface. In short, the particles would never strike side surface 7B

Claim 1 Rejection, cont'd

- Applicable law
  - Proceeding contrary to accepted wisdom in the art is evidence of nonobviousness. See MPEP §2145(X)(D)(3); see also In re Hedges, 783 F.2d 1038, 228 USPQ 685 (Fed. Cir. 1986)
- Applying law to facts
  - Nakamura teaches increasing angle of incidence toward 90 degrees to optimize epitaxial growth
  - Applicant discloses decreasing angle of incidence from 90 degrees to optimize epitaxial lateral overgrowth
  - Claim 1 recites ≤40 degree angle of incidence
  - Invention could not have been discovered by following accepted wisdom of Nakamura's teaching

Claim 1 Rejection, cont'd

- Applicable law
  - If the proposed modification would render the prior art invention being modified unsuitable for its intended purpose, then there is no suggestion or motivation to make the proposed modification. See MPEP §2143.01, 1st ¶ of 5th major heading; see also In re Gordon, 733 F.2d 900,221 USPQ 1125 (Fed. Cir. 1984)
- Applying law to facts
  - O.A. proposes the motivation for combining would be the optimal crystal formed thereby
  - Directing molecular beam perpendicular to substrate surface to otimize the crystal formed thereby, as taught by Nakamura, would prevent the formation of epitaxial lateral overgrowth
  - Applicant's method of claim 1 is directed to achieving epitaxial lateral overgrowth
  - Proposed modification render the prior art invention being modified unsuitable for its intended purpose
  - Therefore, there is no suggestion or motivation to make the proposed modification

Claim 1 Rejection, cont'd

- Applicant discloses in Fig. 3:
  - Dislocations generated in the single crystalline films 4 and 7, from the lattice mismatch between substrate 1 and films 4 and 7, propagate in a direction almost perpendicular to the surface of substrate 1, and not in a direction parallel to the surface (specification, page 4, lines 9-13)
  - Thus, the single crystalline film 8 may have dislocations, but the single crystalline film 9 formed laterally on amorphous film 2 has very few dislocations (specification, page 4, lines 13-16)
  - Single crystalline film 9 formed laterally on amorphous film was characterized by a transmission electron microscope as having a dislocation density of not more than 10^2 cm^{-2} (specification, page 11, lines 23-25, page 12, lines 7-9, lines 18-19, lines 27-28, page 13, lines 21-23, page 14, lines 6-8, page 15, lines 2-4, and page 15, line 27, through page 16, line 1)
  - By contrast to Applicant's superior results, Tanaka discloses a dislocation density in the range of 10^4 to 10^5 cm^{-2} (col. 4, lines 27-29)

super property

- Applicable law
  - "Evidence that a compound is unexpectedly superior in one of a spectrum of common properties … can be enough to rebut a prima facie case of obviousness." In re Chupp, 816 F.2d 643, 646, 2 USPQ2d 1437, 1439 (Fed. Cir. 1987); MPEP §716.02(a), 1st ¶ of 2nd major heading

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Claim 17 Rejection

- Claim 17 recites:
  - Introducing atomic, molecular, or chemical beams onto the surface of a single crystalline substrate to grow a single crystalline film on the exposed surface of the substrate
  - The single crystalline substrate and single crystalline film are of different materials
- Office Action states:
  - Tanaka discloses growing single crystalline GaN on a single crystalline sapphire substrate using an epitaxial lateral overgrowth (ELO) technique (O.A., page 5, 3rd ¶)
  - O.A. acknowledges that Tanaka does not disclose molecular beam epitaxy (MBE) as the method of GaN semiconductor growth (O.A., page 3, 3rd ¶)
  - Continuing, the O.A. states that Tokunaga discloses laterally overgrowing GaAs on an amorphous film (O.A., page 3, 4th ¶)
  - Additionally, the O.A. states that Tokunaga suggests the equivalence of MBE and chemical vapor deposition (CVD) for the growth of epitaxial films (O.A., page 3, 4th ¶)
- Office Action proposes:
  - Based on this information, the Office Action proposes that it would have been obvious to combine the references because Tokunaga suggests an equivalent method of growing selective epitaxial nitride films upon amorphous masking layers (O.A., page 3, 5th ¶)

Claim 17 Rejection, cont'd

- Tokunaka discloses:
  - Tokunaga may suggest the interchangeability of MBE and CVD in the process of forming "a thin film by photolithography of the prior art," (Tokunaga col. 1, lines 24-33)
  - Tokunaga does not suggest interchangeability of MBE and CVD for epitaxially growing a single crystalline film of one material on a single crystalline substrate of a different material
  - To the contrary, Tokunaga discloses that "selective deposition methods are known in which a monocrystal substrate is covered partially with an amorphous thin film, and the same material as the substrate is epitaxially grown only at the exposed portion of the monocrystal substrate" (col. 2, lines 13-17)
  - "[T]hese selective deposition methods rely on growing selectively the monocrystal semiconductor of the same kind from the exposed surface of the monocrystal substrate" (emphasis added) (col. 2, lines 28-31)

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Claim 17 Rejection, cont'd

- Conclusion
  - Tokunaga teaches away from the claimed combination recited in claim 17
  - It is improper to combine references where the references teach away from their combination. See MPEP §2145(X)(D)(2); see also In re Grasselli, 713 F.2d 731, 743 218 USPQ 769, 779 (Fed. Cir. 1983)